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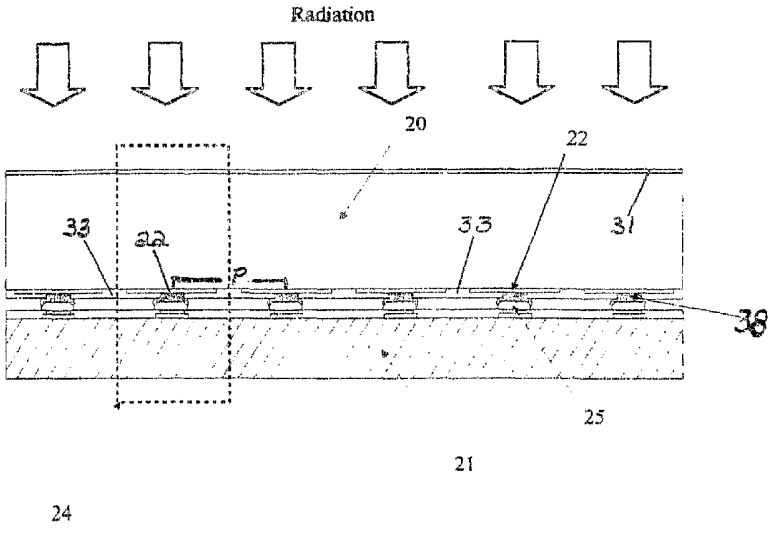
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(54) **Title:** CONDUCTIVE ADHESIVE BONDED SEMICONDUCTOR SUBSTRATES FOR RADIATION IMAGING DEVICES



(57) **Abstract:** The radiation detector/imaging substrate arrays (20) in an x-ray and gamma-ray radiation energy imaging device are described which use an electrically conductive adhesive (38) to provide electron charge signaling continuity between the detector and read-out substrates (21) of the device. The present device utilizes a plurality of electrically conductive bonds (25) each discretely connecting a pixel contact (22) in the pixel pattern to a signal contact in the signal contact pattern, the bonds (25) being electrically conductive adhesive (38). This bonding technique is especially useful in detection/imaging arrays having detector substrates comprising Cadmium and Tellurium compositions. The present invention is practicable with semiconductor detector and read-out substrates with or without "bumped" electrical contact. The electrically conductive bonds (25) utilize either isotropically or anisotropically conductive adhesives (38).

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CONDUCTIVE ADHESIVE BONDED SEMICONDUCTOR SUBSTRATES FOR RADIATION IMAGING DEVICES

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The present application claims the benefit of prior filed U.S. Provisional Application, serial number 60/368,540, filed 29 March 2002, to which the present application is a non-provisional U.S. Patent Application.

Field of the Invention

The present invention is in the field of semiconductor devices for detecting invisible radiant energy. More specifically, the present invention relates to imaging systems for forming an image of an object and having detection means including a Cadmium Telluride substrate bonded to a specific semiconductor arrangement using a conductive adhesive.

Background of the Invention

In the field of semiconductor radiation imaging devices comprising a semiconductor detector substrate solder bump-bonded to a semiconductor processing/readout substrate, the occurrence of "cold" solder joints can be a problem. See patent numbers US 5,379,336; US 5,812,191; EP 1162833; and EP 0421869. Cold solder joints, also called cold welds, can occur in a variety of solder compositions, including solder alloys containing Indium, Lead, Tin and other metals.

This has motivated the field to seek alternative soldering or bump-bonding methods to reduce the occurrence of cold joints, including a low-temperature bump-bonding techniques (see US Pat No. 5,952,646). However, current soldering or the above mentioned bump-bonding techniques cannot fulfill all the requirements of new high-density, imaging device assembly processes which utilize temperature sensitive semiconductor materials in the detector substrates. These temperature sensitive semiconductor detector substrates include some of the currently most promising inter-metallic materials, such as Cadmium Telluride (CdTe) compositions and Cadmium Zinc Telluride (CdZnTe) compositions.

When bonding high density semiconductor substrates together with solder, the interconnection volumes are very small in the resulting imaging devices. This small interconnect area coupled with the relatively more brittle character of some of the promising inter-metallic detector substrates can result in a decrease in the mechanical stability of the interconnection and decreased reliability when solder bump-bonding is used with some of these inter-metallic materials. Additionally, the use of metallic Lead (Pb) in solder to bond the semiconductor substrates increases the amount of this toxic metal potentially exposed to the environment.

Therefore, it would be beneficial to the industry to have a semiconductor substrate bonding technique that does not subject the brittle and temperature sensitive inter-metallic semiconductor materials to excessive heat or pressure. Additionally, it would be beneficial to the industry to have an alternative method for producing semiconductor imaging substrates that is simpler than the current bonding techniques, less susceptible to the problem of cold solder joints or cold welds, and which reduces the amount of metallic lead required to accomplish the bonding process.

Summary of the Invention

The present invention is a digital radiation imaging device and method for producing the device to digitally image radiation in excess of 1keV. The imaging device is relatively robust, reliable and cost effective. The present radiation imaging device comprises a semiconductor substrate which generates charge directly in response to incoming radiation, a readout/processing semiconductor substrate for processing and reading out the generated charge, and an electrically conductive adhesive means for joining or bonding the two semiconductor substrates together.

The adhesives of the present invention create mechanically solid and electrically conductive contacts of joint between the semiconductor substrates. The cured adhesives are also thermally conductive and protect the electrical contacts from the environment. Most often this is achieved by incorporating electrically conductive or fusible particles into a polymer adhesive.

The adhesives can be either isotropic or anisotropic depending on their physical characteristics and how they are applied to a semiconductor substrate, i.e., in discrete locations or as a film. Isotropic adhesives conduct electricity substantially equally well in all directions, once they are cured in the imaging device. Anisotropic adhesives preferentially conduct electricity well in one plane direction, once they are cured in the imaging device. The mating charge signaling contacts between the semiconductor substrate can be either bumped or bumpless to connect a readout CMOS substrate to its matching detector substrate. The connections between the mating charge signaling contacts are accomplished using either isotropically conductive or anisotropically conductive adhesives. This is particularly useful with CdTe or CdZnTe detector substrates, but can be used with other radiation imaging detector substrates, including PbI, HgCdTe, GaAs, when the present benefits are desired.

Brief Description of the Drawings

Fig. 1 is an illustration of the device of the present invention comprising the two dimensional imaging array of a radiation imaging system.

Fig. 2A is a partial cross-sectional side view of an embodiment of the present invention wherein a semiconductor flip-chip substrate is adhesively bonded to a bumped readout CMOS semiconductor substrate using discrete application of a conductive adhesive.

Fig. 2B is an exploded side view of the device of Fig. 2A showing a pixel cell before conductive adhesive bonding of the flip-chip/detector substrate to the bumped CMOS substrate.

Fig. 2C is an exploded side view of the device of Fig. 2A showing a pixel cell after conductive adhesive bonding of the flip-chip substrate to the bumped CMOS substrate.

Fig. 3A is a partial cross-sectional side view of an embodiment of the present invention wherein a semiconductor flip-chip substrate is adhesively bonded to a bumpless readout CMOS semiconductor substrate using discrete application of a conductive adhesive.

Fig. 3B is an exploded side view of the device of Fig. 3A showing a pixel cell before conductive adhesive bonding of the flip-chip substrate to the bumpless CMOS substrate.

Fig. 3C is an exploded side view of the device of Fig. 3A showing a pixel cell after

conductive adhesive bonding of the two bumpless substrates together.

Fig. 4A is a partial cross-sectional side view of an embodiment of the present invention wherein a semiconductor flip-chip substrate is adhesively bonded to a bumped readout CMOS semiconductor substrate using a layer of an anisotropically conductive adhesive, and the directional nature of its conductivity.

Fig. 4B is an exploded side view of the device of Fig. 4A showing a pixel cell before conductive adhesive bonding of the flip-chip substrate to the bumped CMOS substrate.

Fig. 4C is an exploded side view of the device of Fig. 4A showing a pixel cell after conductive adhesive bonding of the flip-chip substrate to the bumped CMOS substrate.

Fig. 5A is a partial cross-sectional side view of an embodiment of the present invention wherein a semiconductor flip-chip substrate is adhesively bonded to a bumpless readout CMOS semiconductor substrate using a layer of an anisotropically conductive adhesive, and the directional nature of its conductivity.

Fig. 5B is an exploded side view of the device of Fig. 5A showing a pixel cell before conductive adhesive bonding of the flip-chip substrate to the bumpless CMOS substrate.

Fig. 5C is an exploded side view of the device of Fig. 5A showing a pixel cell after conductive adhesive bonding of the flip-chip substrate to the bumpless CMOS substrate.

Detailed Description of the Invention

In accordance with a preferred embodiment of the present invention the radiation imaging device comprises a semiconductor substrate for generating charge directly in response to incoming radiation hits, a readout/processing semiconductor substrate for processing and reading out the generated charge and an isotropically conductive adhesive (ICA) for bonding the two substrates together. Such ICAs have a conductive filler with a high filler loading rate, and they are conductive substantially in all directions equally well. Only a minimum bonding pressure is required when bonding with ICAs. Hence, the brittle CdTe or CdZnTe detector substrates are not subjected to excessive pressure and the risk of damage to the detector substrate is minimized.

In another preferred embodiment, the imaging device of the present invention comprises a semiconductor substrate for generating charge directly in response to incoming radiation hits , a readout/processing semiconductor substrate for processing and reading out the generated charge and an anisotropically conductive adhesive (ACA) material for bonding the two substrates together. ACAs also have a conductive filler, but achieve electrical conduction by using conductive filler loading rate which provide conduction substantially across a single plane (e.g., z-plane). In anisotropic adhesives, the loading rates are low enough to ensure that electrical insulation is maintained in the other two physical planes (e.g., the x-y-planes) of the bond interface.

The present electrically conductive adhesives comprise a polymer resin, a curing agent, other additives and conductive filler particles. The polymer resin provides a matrix in which the conductive filler particles are suspended. The adhesive matrix can be either thermosetting or thermoplastic. When thermosetting

polymer resins are cured, a chemical reaction takes place and a three-dimensional network of cross-linked polymers is formed. As result, thermosetting adhesives are relatively temperature stable and do not melt under heating. They are also essentially infusible, insoluble and show good creep resistance. Epoxy resin is the most frequently used thermosetting adhesive matrix.

On the other hand, thermoplastic adhesives are based on a polymer dispersed in a solvent. Curing of such thermoplastic resins is a drying process, where heating evaporates the solvent content of the resin, thus no chemical reaction takes place. Therefore, the adhesive matrix can be re-melted when subjected to temperatures above a specific melting point or melting range. Hence, thermoplastic adhesives can be used in so called polymer bumps where re-melting is needed. Examples of solvent labile polymers useful in the present invention include polyamides and polyesters.

Conduction mechanisms for providing electrical communication between the semiconductor substrates are highly dependent upon the type of conductive particle that is formulated into the adhesive matrix. The adhesive matrix may be filled with metal, metal alloy or metal coated particles. Examples of metal particles practicable in the practice of the present invention include nickel (Ni), gold (Au) or silver (Ag). In the case of ACAs, the conduction mechanism is based upon applying sufficient pressure during assembly in a such way that the metal particles penetrate through the oxide layer into of the semiconductor substrate, and plastically deform the electrical contact metallizations. On the other hand, in the case of ICAs, the electrical connection between the detector substrate and readout CMOS substrate is created by numerous bridged particles, not by single particles (as in ACAs).

Metal coated particles may, for example, comprise polymer spheres which are coated with Ni/Au or Au. The conduction mechanism in this case is based upon applying sufficient pressure during assembly in a such way that the particles themselves plastically deform and result in overall contact area larger the initial contact area. A benefit of using coated polymer particles filler is that the compressible nature of a single polymer particle (or a cluster of particles) will accommodate some horizontal or vertical movement of the joint area, and hence the electrical connection will remain stable during thermal expansion or other movement. Also, compressibility the polymer-cores of coated polymer particles fillers can provide the advantage of compensating small non-coplanarity discrepancies between the planes of the readout CMOS or its bump and pixel contact of the CdTe or CdZnTe detector substrate.

Traditional solder materials, such as tin-lead (SnPb), or low melting point alloys, such as tin-bismuth (SnBi), tin-lead-bismuth (SnPbBi), tin-indium (SnIn), are examples of metal alloy particles utilized in electrically conductive adhesives. An adhesive filled with these type of particles creates small, local solder joints or connections between the readout CMOs' contacts and pixel electrode contacts, while the adhesive matrix simultaneously provides an underfilling. The metallurgical nature of these joints mean that any relaxation of the adhesive matrix, which may occur during the operational lifetime of the particular device, should not affect the electrical continuity of the joints. Also, when the metal filler is metallurgically compatible with the contact metal, a local solder joint is formed even though the melting point of the filer metal or metal alloy is not reached. Bismuth filler with tin contact metal is an example of this technique.

In an alternative embodiment, the filler particles may have a very thin, non-conductive outer surface coating. This very thin insulating coating prevents the

particles from creating electrically conductive bridges across the thickness of the adhesive. However, for those filler particles compressed between the bump and pixel electrode contact during bonding of the two substrates together, the non-conductive coating is broken and an electrically conductive pathway is created. The non-conductive coating may be chosen so that breakage of the coating is accomplished or facilitated by heating. Hence, a high particle-adhesive matrix ratio can be used without the risk of short circuiting.

It is not only the choice of filler material, but also the size and shape of the filler particles that influence the properties of the cured adhesive bonds. Some of the properties of the cured adhesive bonds that can be influenced by particle size and shape are: electrical conductivity, thermal conductivity, tensile strength, viscosity, weight loss and rheology. The filler particles may be different configurations as selectable by one of ordinary skill in the art. For example, the filler particles may be flakes, spheres or other shapes, and may have a size ranging from nanometers to several micrometers.

Due to their nature different adhesive types have to be applied to the contact areas accordingly. ICAs have to be applied with high accuracy. For example, screen printing, dispensing or pin-transfer methods can be used. Also, if either the readout CMOS substrate or the detector substrate has bumps, the adhesive can be applied with dipping the CMOS or detector bumps into the ICA. Furthermore, if the adhesive matrix is composed of thermoplastic polymers, the ICA can be cured before actual bonding and a so called polymer bump is formed. This is followed by a normal bump-bonding where the polymer bump re-melts during bonding and an electrical connection is formed. These polymer bumps can also be formed with a masking process, and hence no under bump metals (UMP) or bumps have to be initially deposited on the readout CMOS substrate or the

detector substrate. However, additional metal layers may be deposited on top of the conductor in order to improve conductivity and material compatibility (and hence improve reliability). Furthermore, a thermoplastic photoresist mask may be used which, if not removed, can work as an underfill. On the other hand, ACAs can be applied to the whole joining area, not only on each contact or joint area, as ACAs achieve electrical conductivity only in a single plane direction. This greatly reduces the accuracy requirements on whatever method is used to apply the conductive adhesive. Additionally, the conductive adhesive may also be provided as a film which has either randomly or uniformly distributed filler particles in it. This can further decrease the risk of short circuiting due to bridged particles and therefore are often used in very fine pitch applications.

Referring now to the drawings, the details of preferred embodiments of the present invention are graphically and schematically illustrated. Any like elements in the drawings are represented by like numbers, and any similar elements are represented by like numbers with a different lower case letter suffix.

FIG. 1 schematically illustrates an imaging system **10** which consists of one or more imaging devices **11**. The imaging device **11** comprises of a readout CMOS substrate **21** and image detector substrate **20** which are bonded together with an electrically conductive adhesive **25**. In the preferred embodiment shown, the imaging device **11** is composed of a plurality of individual pixel cells **24**. These pixel cells **24** detect high energy radiation (indicated by the large arrows in figures) and pass the collected information through the readout CMOS **21** to the control electronics for further processing and analysing.

FIG. 2A is a schematic cross section of an adhesive bonded imaging device **11**. In this example the image detector substrate **20** is bonded to a bumped readout

CMOS **21** with a conductive adhesive **38**. In the case illustrated either an isotropically conductive adhesive (ICA) **27** or an anisotopically conductive adhesive (ACA) **28** could have been used as the conductive adhesive. **FIGs. 2B** and 2C are more detailed schematic illustrations of a single pixel cell 24 before (**2B**) and after bonding (**2C**). The image detector **20** side of a single pixel cell **24** comprises a semiconductor detector substrate **32** which has a continuous electrode **31** on the back side and pixel contacts (electrodes) **22** on the front side of the detector substrate **32**. The pixel contacts **22** are protected with a detector insulation (passivation) layer **33** having small detector openings **42** for electrical connection pathways.

On the readout CMOS substrate side of the pixel cell **24** is a corresponding CMOS pixel signal circuit **36**. This CMOS signal circuit **36** of the pixel cell **24** has a signal contact **37** conductor which is connected (see **FIG. 2C**) to the pixel contact **22** of the semiconductor detector substrate **32** by means of a conductive **38**. The readout substrate **21** in this example has bumps **25** comprise of, for example, nickel-gold (Ni/Au), nickel-palladium (Ni/Pd), normal solder or a low temperature solder material. Although shown in **FIG. 2B** as being disposed the CMOS readout substrate **21**, the bump **25** alternatively may be disposed on the pixel contact **22** of the detector substrate **20** or on the contacts **22 & 37** of both substrates **20 & 21**.

As can be seen from **FIG. 2A-C**, the conductive adhesive **38** is discretely applied directly on the bump **25**. For a conductive adhesive (e.g., an ICA) which is conductive substantially equally in all directions, discrete application directly on a bump **25** or a contact **22 & 37** does not create a signal loss problem from shorting. Application of the conductive adhesive **38** can be done with screen printing, dispensing, pin-transfer methods or other methods known to one of skill in the art. The conductive adhesive **38** itself is a matrix composed of an adhesive

or cement (e.g. epoxy adhesive) which is filled with electrically conductive or fusible particles **39** (in **FIGs. 4A-4C** and **FIGs. 5A-5C**). These particles **39** can be, for example, metal (e.g. Ag), metal alloy (e.g. Ni/Au) or metal coated particles (e.g. polymer sphere coated with Ni/Au). ICAs consist, in general, of about 35-85 vol-% randomly dispersed filler particles **39**, but the filler material, size and amount is determined by the application, the contact materials used , and the pitch **P** of the pixels and the gap **G** between the image detector **20** and readout CMOS **21.**

Outside the connection area, the CMOS pixel circuit **36** is protected from the environment by the CMOS insulation or passivation **35.** In order to improve the compatibility of the materials (in connection with each other) and also to improve adhesion, mechanical and/or electrical conductivity, one or multiple layers of under bump metals (UBM) **34** can be applied between the bump **25** and a pixel circuit signal contact **37**. Furthermore, an imaging device bonded with a conductive adhesive **38** can be underfilled if increased reliability is needed.

FIG. 3A shows a detector substrate **20** which is bonded to a readout CMOS **21** with a conductive adhesive **38**, as in **FIGs. 2A-2C**. However, unlike in **FIGs. 2A-2C**, in this example the readout CMOS **21a** is bumpless. The bump **25** and UMB **34** may be replaced with additional metal layer **26** in order to improve conductivity and material compatibility (and hence improve reliability), but still no bumping is needed. As **FIGs. 3B** and **3C** illustrate, the bonding process with a bumpless readout CMOS substrate **21a** is very similar as it is with a bumped readout CMOS substrate **21**.

Generally, the conductive adhesive **38** is not cured before bonding. However, if the adhesive matrix of the conductive adhesive **38** is comprised of

thermoplastic polymers, the adhesive may be cured to form a "polymer bump" before actual bonding of the two semiconductor substrates **20** & **21**. This is followed by a normal bump-bonding technique where the polymer bump is re-melted during bonding and forms an electrical connection. Polymer bumps can be formed, for example, with a masking process. Alternatively, a photoresist mask may be used as a stencil and the conductive adhesive **38** screen printed onto the signal contacts **37** or pixel contacts **22**. This process step may also take place prior to dicing (e.g., of the CMOS chips from the wafer). Furthermore, no additional underfill is needed if the photoresist is also composed of thermoplastic polymers and is not removed from the readout CMOS substrate **21** or the detector substrate **20**.

FIGs. 4A-4C and **FIGs. 5A-5C** are respectively schematic presentations of a bumped and a bumpless readout CMOS substrate **21**, which are bonded to a detector substrate **20** with a conductive adhesive **38**. As the figures demonstrate, an ACA **28** (Fig. 5B) contains fewer filler particles than an equivalent volume of an ICA **27** (Fig. 4B), i.e., an ACA **28** has a lower filler loading rate than an ICA **27**. An ACA **28** conducts electrical charge only across a single plane (e.g., z-axis) when the filler particles **39** are compressed between, for example, the pixel contact **22** and the bump **25**. Moreover, ACAs **28** may be applied to the whole joining surface areas, not only the contact areas. Additionally, an ACA **28** may be configured as a film layer which is placed between the readout CMOS substrate **21** and detector substrate **20**. The adhesive film may consist of one or multiple layers which all may have different properties according to the application. Furthermore, the conductive filler particles **39** may be either randomly or uniformly distributed in the film.

While the above description contains many specifics, these should not be construed as limitations on the scope of the invention, but rather as exemplifications of one or another preferred embodiment thereof. Many other variations are possible, which would be obvious to one skilled in the art. Accordingly, the scope of the invention should be determined by the scope of the appended claims and their equivalents, and not just by the embodiments.

WHAT IS CLAIMED IS:

Claims

1. An x-ray and gamma-ray radiation energy imaging device comprising:

a detector substrate, the detector substrate having an electrode surface and a pixel surface, and disposed to convert said radiation energy impinging on the electrode surface to electrical charges, and with the pixel surface having a plurality of pixels and associated pixel contacts thereon with the pixels for collecting the electrical charges and the pixel contacts disposed in a pixel contact pattern;

an ASIC readout substrate having a readout surface disposed opposite the pixel surface of the detector substrate, a plurality of pixel signal circuits disposed on the readout surface and the signal circuits each having a signal contact processed on the readout surface in a signal contact pattern, the signal contacts being inputs to the signal circuits of the ASIC readout substrate; and

a plurality of electrically conductive bonds each discretely connecting a pixel contact in the pixel pattern to a signal contact in the signal contact pattern, the bonds consisting essentially of an electrically conductive adhesive.

2. The radiation energy imaging device of claim 1, wherein the detector substrate comprises an element selected from the group consisting of Cadmium and Tellurium.

3. The radiation energy imaging device of claim 1, wherein the electrically conductive bonds comprise bump-bonds.

4. The radiation energy imaging device of claim 1, wherein the electrically conductive bonds comprise an isotropically conductive adhesive.

5. The radiation energy imaging device of claim 1, wherein the electrically conductive bonds comprise an anisotropically conductive adhesive.

6. A method of producing an x-ray and gamma-ray radiation energy imaging device of claim 1 comprising the steps of:

providing a semiconductor detector substrate and an ASIC semiconductor readout substrate, the detector substrate having an electrode surface and a pixel surface, and disposed to convert said radiation energy impinging on the electrode surface to electrical charges, and with the pixel surface having a plurality of pixels and associated pixel contacts thereon with the pixels for collecting the electrical charges and the pixel contacts disposed in a pixel contact pattern, and the ASIC readout substrate having a readout surface with a plurality of pixel signal circuits disposed on the readout surface and the signal circuits each having a signal contact processed on the readout surface in a signal contact pattern corresponding to the pixel contact pattern, the signal contacts being inputs to the signal circuits of the ASIC readout substrate;

applying a conductive adhesive to at least one of a set of contacts selected from the group consisting of the pixel contacts and the signal contacts;

juxtapositioning the pixel surface of the semiconductor detector substrate with the readout surface of the semiconductor readout substrate, with the pixel contacts closely proximate corresponding signal contacts on the semiconductor readout substrate; and

causing the conductive adhesive of the conductive adhesive coated contacts under appropriate conditions of heat and pressure to conductively

adhere the pixel contacts of the detector substrate to the corresponding signal contacts on the semiconductor readout substrate to produce the radiation energy imaging device of claim 1.

7. A method of producing a radiation energy imaging device of claim 6, wherein the applying step comprise:

applying a conductive adhesive to at least one of substrate surfaces selected from the group consisting of the semiconductor detector surface and the semiconductor readout surface to provide a conductive adhesive coated semiconductor substrate face with conductive adhesive coated contacts.

8. The method of producing a radiation energy imaging device of claim 6, wherein the conductive adhesive is an isotropically conductive adhesive.

9. The method of producing a radiation energy imaging device of claim 6, wherein the conductive adhesive is an anisotropically conductive adhesive.

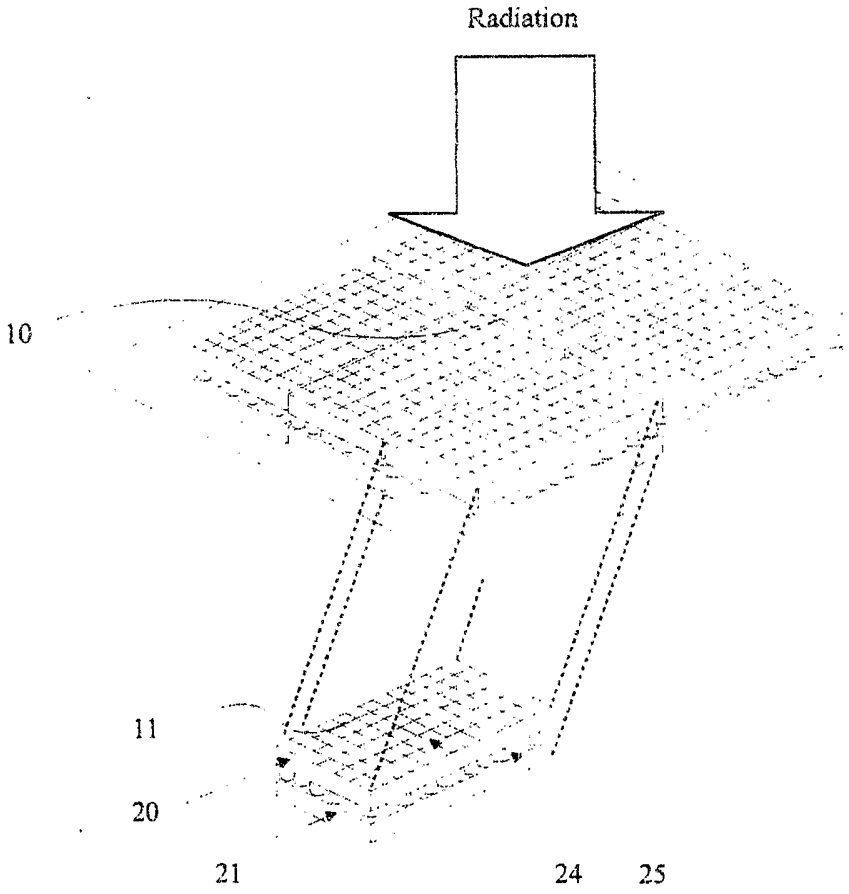


FIG. 1

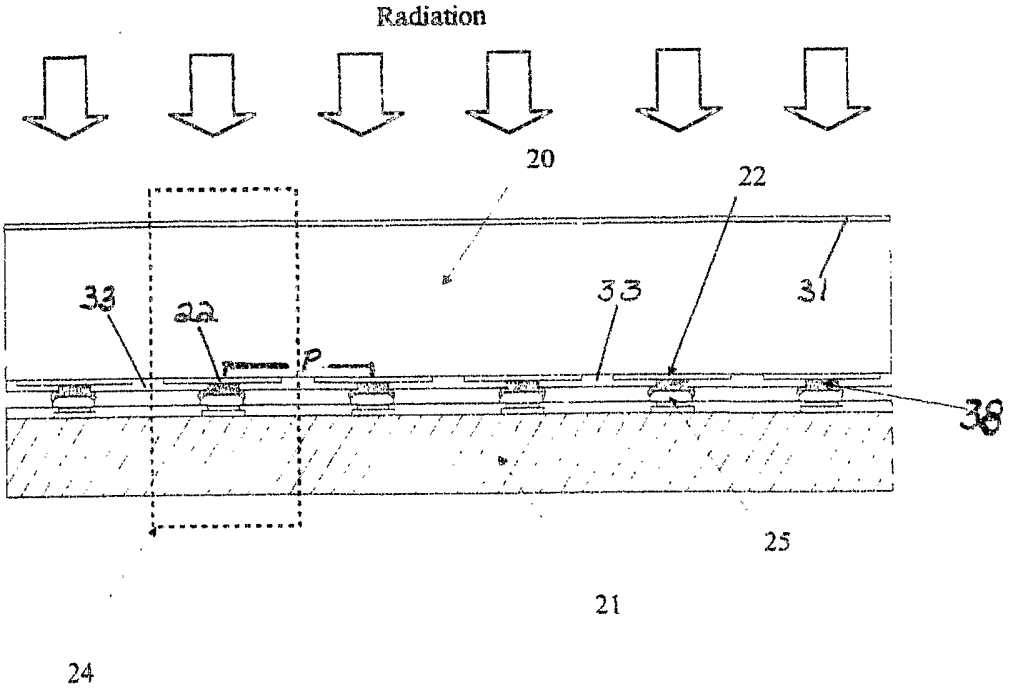


FIG. 2A

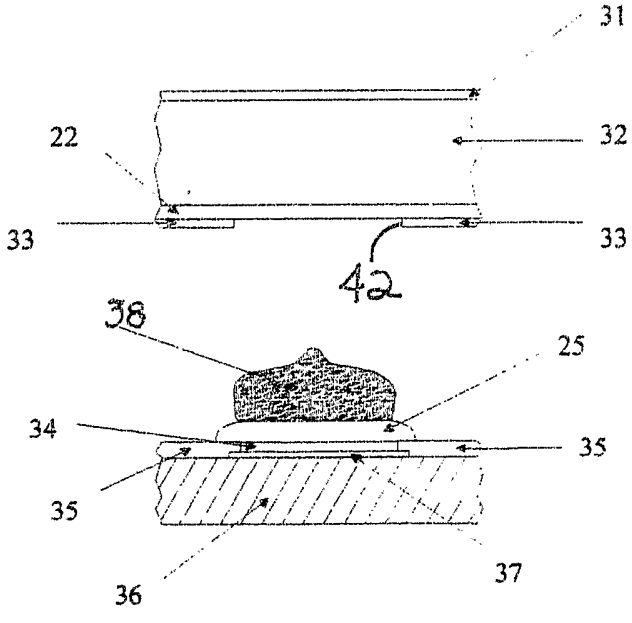


FIG. 2B

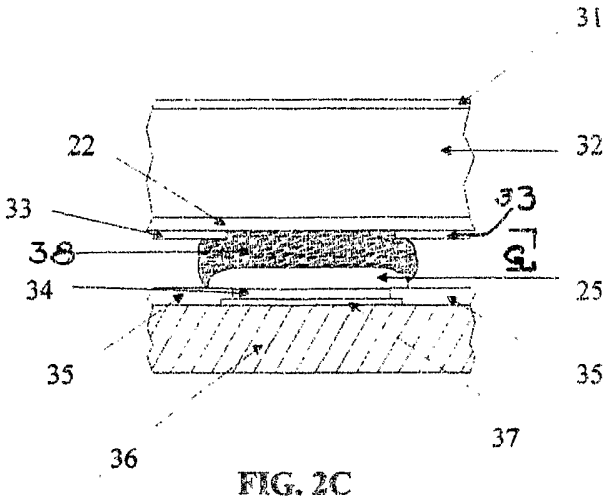


FIG. 2C

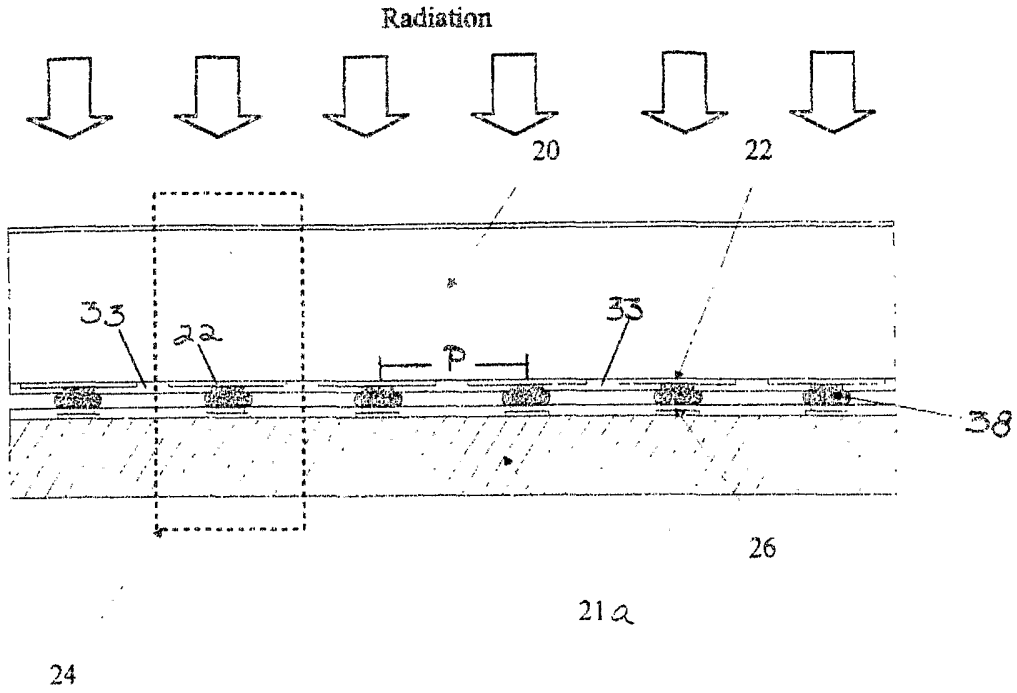


FIG. 3A

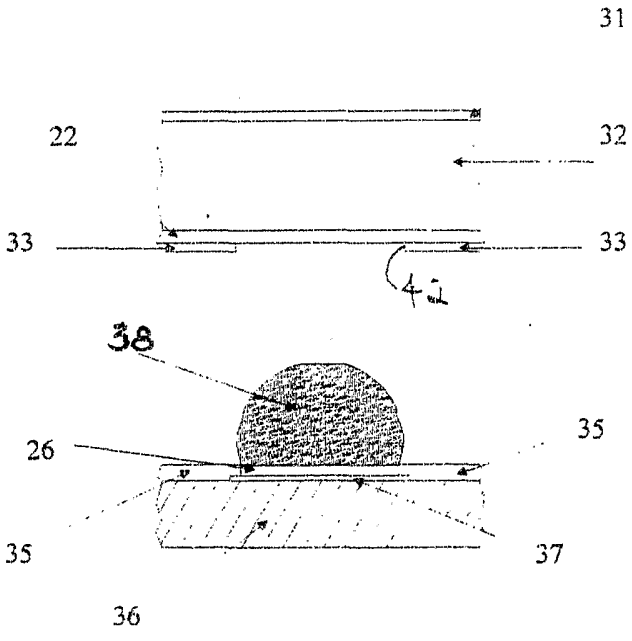


FIG. 3B

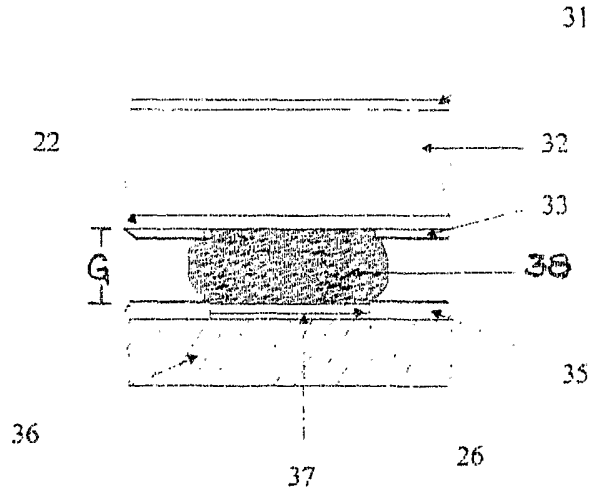


FIG. 3C

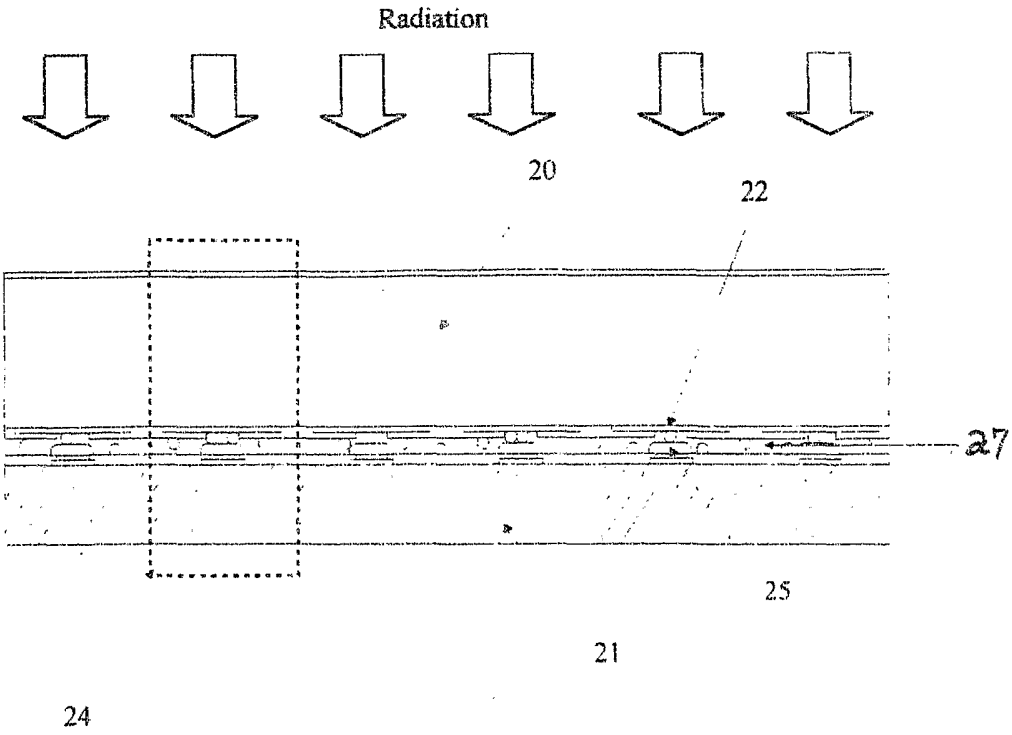


FIG. 4A

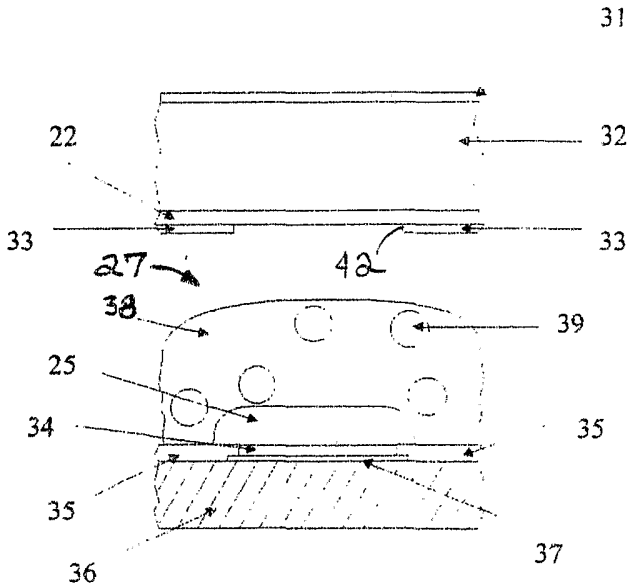


FIG. 4B

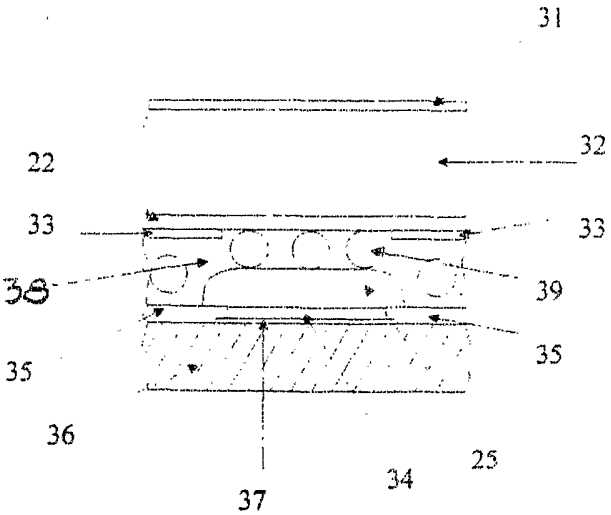


FIG. 4C

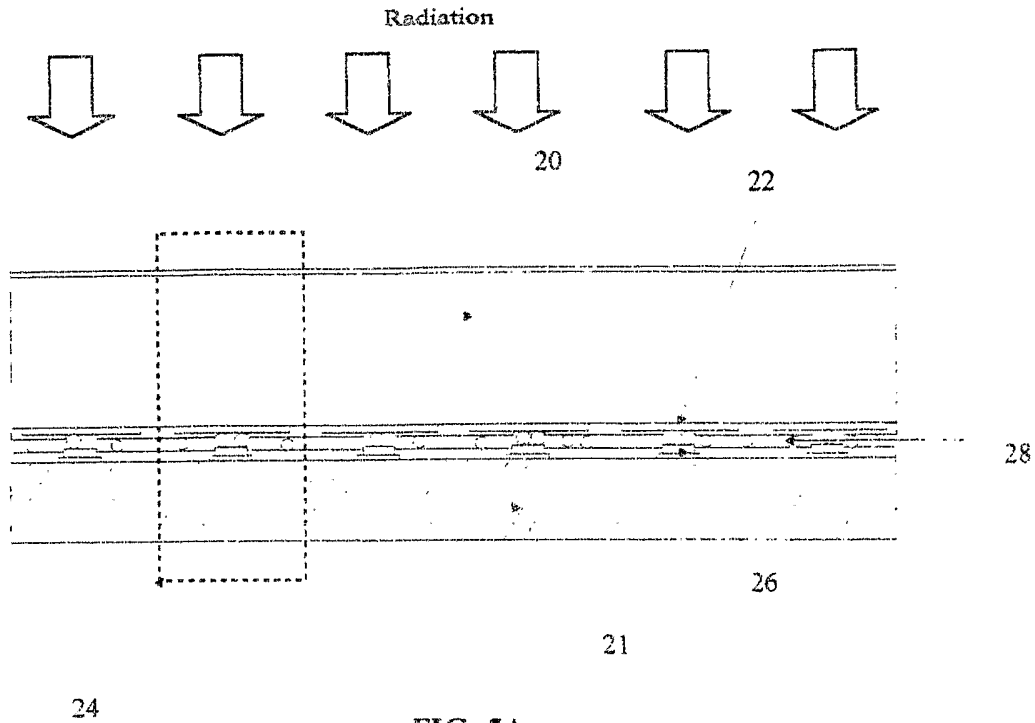


FIG. 5A

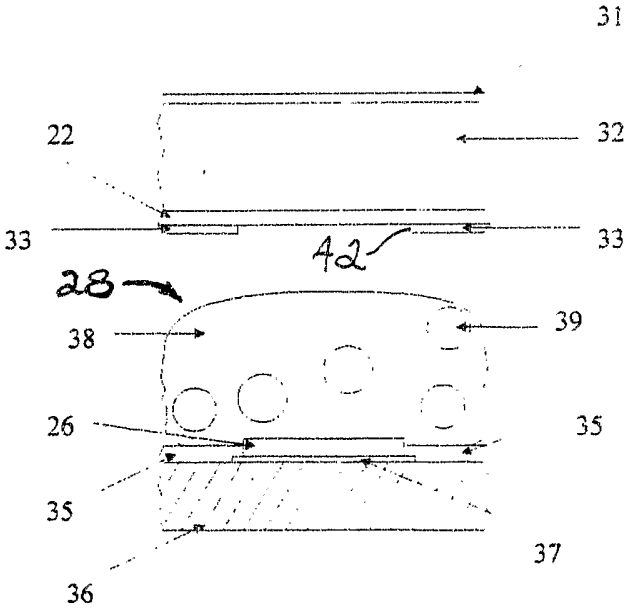


FIG. 5B

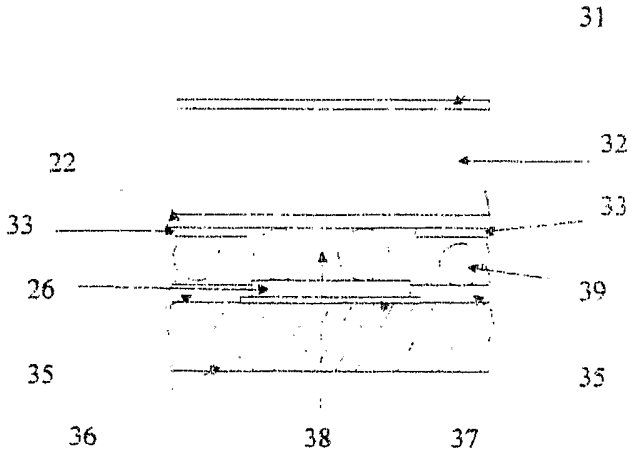


FIG. 5C

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US03/13332

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : H01L 27/00; G01T 1/161
US CL : 250/370.09, 252.1, 208.1

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 250/370.09, 252.1, 208.1, 370.01, 370.11, 370.13, 363.05, 363.07, 363.09, 366, 369

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Please See Continuation Sheet

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6,323,475 B1 (SPARTIOTIS et al) 27 November 2001 (27.11.2001), see Figures 1, 2, 4; Columns 4-8.	1-9
X	US 6,194,715 B1 (LINGREN et al) 27 February 2001 (27.02.2001), see Figure 3a; Columns 6-9.	1-9
X	US 5,886,353 A (SPIVEY et al) 23 March 1999 (23.03.1999), see abstract.	1, 3, 6, 7

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

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Date of the actual completion of the international search
11 July 2003 (11.07.2003)

Date of mailing of the international search report
28 JUL 2003

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Form PCT/ISA/210 (second sheet) (July 1998)

INTERNATIONAL SEARCH REPORT

PCT/US03/13332

Continuation of B. FIELDS SEARCHED Item 3:
USPTO WEST 2.0
search terms: imaging device, detector substrate, ASIC readout, electrodes, contact bump, cadmium, tellurium, pixel, readout surface